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# METHODS AND COSTS OF MILLING FELDSPAR AT THE MINPRO PLANT, TENNESSEE MINERAL PRODUCTS CORPORATION, SPRUCE PINE, N. C.

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# METHODS AND COSTS OF MILLING FELDSPAR AT THE MINPRO PLANT, TENNESSEE MINERAL PRODUCTS CORPORATION, SPRUCE PINE, N. C.[1]

By B. C. Burgess[2]

This paper, describing the milling practices at the Minpro plant of the Tennessee Mineral Products Corporation, Spruce Pine, N. C., is the first of a series being prepared by the U.S. Bureau of Mines on feldspar milling methods and costs in the various feldspar producing areas in the United States. It describes not only the latest practices in feldspar grinding but includes studies of the cost of producing ground feldspar. These cost studies, obviously of interest to every consumer and purchaser of feldspar and to all feldspar grinders, are also of value to the small operator, who is generally prone to understimate his real costs. It describes the latest practices in feldspar milling and includes detailed costs of grinding. The cost tabulations presented show operating expenditures only and not total production costs. Details of costs are given only to the extent that they are essential to the technical discussion and study of the methods employed.

A description of the recently installed milling unit for the preparation of granular glasspar by graded crushing and magnetic separation is of particular interest. It illustrates how highly specialized feldspar milling has become, and to what an extent grinders are going to supply consumers with the products best suited for their particular needs.

## ACKNOWLEDGMENT

The author is indebted to F. W. Horton, mining engineer, U. S. Bureau of Mines, for assistance in the preparation of this paper.

## INTRODUCTION

The Tennessee Mineral Products Corporation is engaged in mining and milling feldspar near Spruce Pine, N. C., a town of about 1,600 population on the Carolina, Clinchfield & Ohio Railway, 63 miles southeast of Johnson City, Tenn., and 30 miles northwest of Marion, N. C. The company operates a modern feldspar grinding plant with a rated monthly capacity of more than 6,000 tons of ground and granular spar. The mill site comprises 21 acres paralleling the North Estatoe River and lying between the State highway and the Clinchfield Railway. In addition to this site, the company owns 138 acres of mineral property in fee and holds leases covering approximately 1,500 acres of mineral land contained in 12 separate tracts, selected with a view to providing the plant with the necessary reserve tonnage of all grades of feldspar available in the district.

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1 - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6488."

2 - One of the consulting engineers, U. S. Bureau of Mines, and manager of the Tennessee Mineral Products Corporation.

## HISTORY

The Tennessee Mineral Products Corporation had its beginning in 1921 when it undertook the mining of crude feldspar from the Wiseman property on Beaver Creek, Mitchell County, N. C. This property was abandoned in the summer of 1922 after extensive prospecting and development work failed to disclose enough feldspar of salable grade to permit profitable operation. The company then undertook a careful reconnaissance of the local feldspar area which is some 12 to 15 miles wide and 25 to 30 miles long. An exhaustive study was also made of milling and market conditions and, as a result, the company decided to enter the milling field. As a basis of operations, the Deer Park mines were acquired from the Blue Ridge Mining Co. on October 1, 1922, and as a successful source of high-grade potash spar, they have been of inestimable value in the growth and development of the company.

In 1923 the company installed a continuous grinding unit at Bristol, Va., and entered into an agreement making the Roessler and Hasslacher Chemical Co. of New York City its exclusive sales agent.

As a result of the study which the company's engineers made of the general situation in the feldspar industry, they decided that if any real progress was to be attained, chemical control throughout the milling process was essential. Accordingly, a laboratory was equipped at Bristol and complete chemical analyses were made of all crude spars and ground products. Screen tests were also made on all ground spars. At first, the trade received the new analyzed feldspars with the usual suspicion in the consideration of any new product. Only after concerted effort by the sales organization was the first carload sold to a whiteware plant and although this trial shipment was satisfactory it was not until June, 1923, three months after the first shipment, that a second carload order was received. Sales increased satisfactorily thereafter, the trade gradually beginning to appreciate the analysis service, so that by January, 1924, a sufficient market had been built up for Minpro feldspar to permit continuous operation of the mines and mill.

During August and September, 1923, the writer, with officials of the company, made a tour of all the feldspar deposits in the eastern United States and Canada, spending a sufficient length of time at each to note the type of deposit, the size and extent to which it was developed, the occurrence and distribution of the mineral and the method of mining. Wherever there was a feldspar grinding plant at the mine or along the route, it also was visited and its flow sheet, construction and operation studied. The information gathered on this trip of observation was utilized so practically as a basis for future operations that it seems pertinent to mention it here. Summarizing the information obtained on this trip and acquired from experimental work at the Bristol plant and from milling operations during 1924 and 1925, the company was able to draw the following conclusions as to the requisites of a larger grinding plant:

1. Two or more grades of spar could be separated economically from a run-of-mine product on a picking belt.

2. Crude spars should be segregated in storage.

3. Dry spar is essential for economical fine grinding and is produced most economically in a rotary dryer.

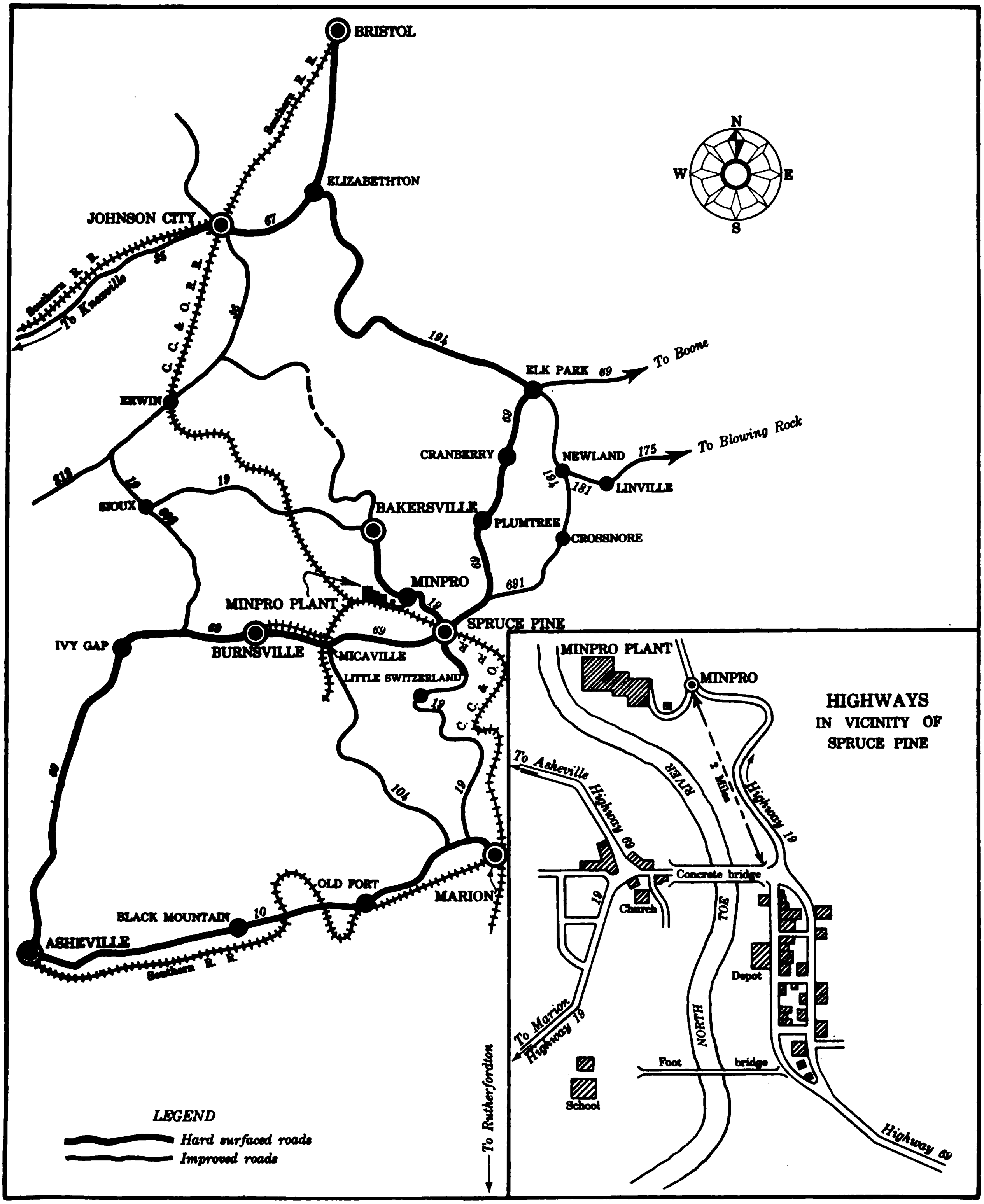

Figure 1.—Road map showing location of Minpro plant

4. Intermediate storage bins of sufficient size to allow operation at full capacity entirely from analyzed spar should be provided for crushed spar after its mechanical sampling.

5. These intermediate storage bins should be arranged so as to permit economical mixing to meet the customer's specifications.

6. Closed-circuit grinding with conical mills is more efficient than stage grinding.

7. A tube mill can be used economically to regrind the oversize from air separators when grinding finer than 140 mesh.

8. When using a continuous grinding process, mixtures must be carefully "neutralized" to provide desired changes in analysis for different shipments.

9. Reasonably close sizing can be obtained in the larger sizes of air separators by using different widths of baffle rings, provided the feed is thoroughly dry and constant in quality.

10. Great care must be taken in handling ground feldspar to keep it clean; small quantities of foreign material show up as specks in ware, although they do not show in an analysis.

As the Bristol plant was nearing full capacity, plans were made for a much larger unit, embodying all the improvements then known to the company and sufficiently flexible to permit changes and additions. Building of this new plant was started at Spruce Pine in February, 1926, and completed in December of that year. In August, 1927, the Bristol unit was moved to a place provided for it in the Spruce Pine plant. In 1928, both of these units being sold to capacity, a third unit was added; and a fourth unit, exclusively for the production of granular glasspar, has just been completed (January, 1931).

As its mines have always been developed well in advance of requirements, the company has never been in danger of having inadequate supplies of crude spar.

## LOCATION OF PLANT AND MOVEMENT OF CRUDE FELDSPAR TO THE MILL

The plant is located on State Highway No. 19, 2 miles north of Spruce Pine on the north bank of the North Estatoe River and adjoining the Carolina, Clinchfield & Ohio Railway (see fig. 1). The company's principal producing properties, the Deer Park mines, are situated about three-quarters of a mile down the river on the opposite bank and are connected with the mill by a narrow-gage railroad and a 5-ton Flory suspension cableway. The 2 1/2-ton buckets in which the spar comes from the Deer Park mines are conveyed by this cableway from the incoming terminal of the narrow-gage railroad to the mill across the river. Crude spar and mill supplies arriving via the Clinchfield Railway are also transferred to the mill by this cableway.

The plant has two sidings on the Clinchfield Railway, one for unloading crude spar on its arrival at the plant and another for shipment of the finished product.

Crude spar arrives at the plant in three ways:

1. By wagon and motor truck from about 60 different mines, either leased by the company or privately owned. On account of the prevalence of hard-surfaced roads it is in some cases profitable to bring spar by motor truck from mines 18 miles away, although the average haul is probably not more than 6 miles.

2. By the Clinchfield Railway which brings spar from mines more accessible to the railroad than to motor haulage.

3. By narrow-gage railroad from the company's Deer Park mines.

## CHARACTER OF CRUDE SPARS

With 60 or more different sources of supply, the physical character and chemical composition of the crude spars arriving at the mill vary between wide limits and afford ample means for producing the 99 standard grades of original and mixed spars that the company offers to the consumer.

Crude spars coming to the mill range in size from fines to lumps weighing sometimes as much as 200 pounds. These last, however, are exceptional, and the average size of the pieces is about 6 inches in diameter. On its arrival at the plant the purchased spar, already hand-sorted into different grades and containing only a small proportion of fines (usually less than 2 1/2 per cent through 3/8-inch mesh), is dumped directly into the crude storage bins. Feldspar from the Deer Park mines, on the other hand, is generally run-of-mine and is crushed and hand-sorted on a picking belt before it goes to the crude storage bins. The following table shows the analyses and fusion data of 35 characteristic crude spars coming to the mill:

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## ANALYSES AND FUSION DATA OF TYPICAL FELDSPARS AVAILABLE TO PRODUCERS IN THE SPRUCE PINE DISTRICT

| No. | Per cent | | | | | | | | | Fuse at cone | Color after fusion |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $K_2O$ | $Na_2O$ | Loss on ignition | Total | | |
| 1 | 66.40 | 18.84 | 0.11 | 0.20 | Trace | 11.72 | 2.65 | 0.22 | 100.14 | 8+ | Good. |
| 2 | 68.03 | 17.73 | 0.07 | .78 | do. | 10.81 | 2.55 | .11 | 100.08 | 8+ | do. |
| 3 | 72.30 | 16.74 | .16 | .93 | do. | 4.31 | 5.62 | .23 | 100.29 | 6½ | do. |
| 4 | 70.10 | 18.69 | .11 | 1.00 | do. | 1.54 | 7.43 | .15 | 99.82 | 6 | do. |
| 5 | 71.61 | 17.68 | .15 | 1.49 | 0.03 | 1.43 | 7.02 | .43 | 99.84 | 6 | do. |
| 6 | 71.66 | 17.44 | .12 | 1.48 | do. | 1.63 | 7.30 | .18 | 99.81 | 6 | do. |
| 7 | 71.68 | 17.93 | .13 | 1.25 | do. | 1.37 | 7.21 | .36 | 99.93 | 6–6½ | do. |
| 8 | 74.05 | 16.09 | .11 | 1.45 | .02 | 2.60 | 5.52 | .23 | 100.10 | 7 | do. |
| 9 | 68.78 | 18.62 | .11 | 1.80 | .01 | 5.36 | 5.08 | .29 | 100.05 | 6 | do. |
| 10 | 63.12 | 23.56 | .09 | 5.04 | .01 | .92 | 7.13 | .18 | 100.05 | | do. |
| 11 | 69.45 | 18.95 | .16 | 3.70 | Trace | 2.72 | 5.11 | .21 | 100.24 | 7 | do. |
| 12 | 66.20 | 20.93 | .12 | 2.65 | do. | 2.79 | 7.48 | .33 | 100.50 | 5–6 | do. |
| 13 | 66.70 | 18.43 | .07 | .20 | do. | 12.38 | 2.02 | .22 | 100.02 | 8 ½ | do. |
| 14 | 67.25 | 18.25 | .10 | .55 | do. | 11.48 | 2.01 | .35 | 99.99 | 8½ | do. |
| 15 | 67.01 | 18.31 | .09 | .43 | do. | 11.15 | 2.63 | .32 | 99.94 | 8½ | do. |
| 16 | 66.48 | 18.70 | .08 | .32 | do. | 11.96 | 2.20 | .31 | 100.05 | 8½ | do. |
| 17 | 66.25 | 18.74 | .11 | .40 | do. | 12.13 | 1.82 | .70 | 100.15 | 9 | do. |
| 18 | 65.80 | 19.17 | .09 | .52 | do. | 12.03 | 1.49 | .72 | 99.82 | 9½ | do. |
| 19 | 68.18 | 17.89 | .11 | .60 | do. | 11.33 | 1.81 | .49 | 100.41 | 9½ | do. |
| 20 | 66.13 | 18.38 | .06 | .50 | .04 | 11.93 | 2.47 | .31 | 99.82 | 8½ | do. |
| 21 | 68.12 | 18.17 | .15 | .62 | .01 | 9.21 | 2.84 | .79 | 99.91 | 8+ | do. |
| 22 | 70.45 | 16.54 | .11 | .40 | Trace | 9.50 | 2.59 | .40 | 99.99 | 8½ | do. |
| 23 | 67.20 | 18.09 | .15 | .35 | .04 | 11.25 | 2.50 | .27 | 99.81 | 8+ | Fair. |
| 24 | 68.40 | 17.63 | .12 | .35 | Trace | 10.88 | 1.66 | .87 | 99.91 | 9 | Good. |
| 25 | 71.45 | 16.25 | .10 | .30 | do. | 9.05 | 2.53 | .66 | 100.34 | 9½ | do. |
| 26 | 71.04 | 16.61 | .09 | .62 | do. | 8.27 | 3.07 | .33 | 100.03 | 8 | Fair. |
| 27 | 71.19 | 16.69 | .08 | .45 | do. | 8.53 | 2.82 | .27 | 100.03 | 8+ | Good. |
| 28 | 70.55 | 16.91 | .14 | .70 | do. | 8.09 | 3.61 | .22 | 100.22 | 8– | Fair. |
| 29 | 66.60 | 19.06 | .09 | .65 | do. | 9.46 | 4.31 | .14 | 100.31 | 7½ | Good. |
| 30 | 67.20 | 19.69 | .11 | 1.45 | do. | 5.43 | 5.99 | .33 | 100.20 | 6–6½ | do. |
| 31 | 69.26 | 17.72 | .10 | 1.10 | do. | 6.85 | 4.88 | .29 | 100.20 | 7–7½ | do. |
| 32 | 69.58 | 17.47 | .17 | .78 | do. | 8.91 | 3.10 | .40 | 100.41 | 8 | Specky. |
| 33 | 70.03 | 18.95 | .08 | 1.27 | do. | 1.03 | 8.16 | .30 | 99.82 | 5½–6 | Good. |
| 34 | 71.93 | 16.70 | .16 | .67 | .01 | 6.31 | 3.94 | .33 | 100.05 | 7 | Specky. |
| 35 | 62.18 | 24.88 | .10 | 4.90 | .07 | .13 | 7.45 | .28 | 99.99 | 11 | Good. |

## PRESENT PLANT

As the present Minpro plant embodies all the ideas developed through the Company's research and operating experience since its inception, it will be described in detail, particularly the important features of chemical control and its concomitants of unusually complete segregation of individual spars in crude storage, automatic sampling, "neutralization" during continuous grinding, and the great flexibility of its flow sheet.

Figure 2 shows the plan of the plant and Figure 3 its graphical flow sheet. Details of equipment not described in the text are listed under "Details of Equipment," page 17. The numbers in the text refer to corresponding numbers on the graphical flow sheet and in the list of details.

## PREPARING CRUDE SPAR

All spar broken in the company's Deer Park mines is generally hoisted and sent to the plant as run-of-mine without any sorting except the picking out of large blocks of mica. This spar is carried by the narrow-gage railroad and cableway, previously mentioned, to a 200-ton storage bin which takes up the surge between the cableway and sorting plant.

The Flory cableway of 2-inch wire rope has a span of 635 feet and is operated by the double-drum, spur-gear, friction cableway hoist run by a 70-hp. motor (1).

Spar from the 200-tons primary bin is fed onto a grizzly made of deformed steel bars spaced 4 inches apart by a 48-inch Stephens-Adamson apron feeder (2) driven from a jack shaft run by the crusher motor. Large pieces of No. 1 potash spar are picked directly from the apron feeder and chuted to a small bin beneath, from which they are transferred to a crude bin containing the same grade of spar. A speed adjustment on the feeder and an electric signal system connecting with the picking-belt room permits regulation of the feed to the picking belt. The oversize from the 4-inch grizzly goes to a 15 by 24 inch Allis jaw crusher set to crush to 4 inches and driven by a 60-hp. motor (3). Spar from the crusher and undersize from the 4-inch grizzly fall upon an 18-inch conveyor (4) which carries them to a 1/2-inch grizzly of deformed steel bars.

The fines through this small grizzly go to a waste dump and the oversize to a 30-inch, 4-ply rubber picking belt, 138 feet long (5) provided with chutes on each side between which the pickers stand. These chutes connect with thirteen 8-ton transfer bins. A tram-car line beneath these bins and over the crude-spar bins permits the transfer of the picking-belt products to any of the crude bins. The transfer bins can be by-passed so as to drop the picking-belt products directly to the crude bins beneath.

Sixteen women and girls and three men is the average crew on the picking belt. They select 25 to 40 tons of material from the 70 to 80 tons run over the picking belt in 10 hours, the quantity removed depending upon the quality and size of material from which it is picked. One of the men is foreman and the two other men are cobbers. Six products are picked from the belt, all from material from one mine or from that of two or more mines combined.

The first girl picks pure flint, the next two remove No. 1 potash spar. Then two girls pick out No. 1 soda spar. Following these, two or three girls pick No. 2 potash spar. The balance of the girls, excepting one picking mica, remove whatever spar remains on the belt. This last product is all classed as No. 2 soda grade. Whatever spar is saved by the two men cobbing at the discharge end of the belt also goes into this grade. The discharge from the belt falls into a bin from which it is trammed to the waste pile. Women have been found to grade the spar more carefully than men and they work for only a little more than half the wages it would be necessary to pay men for this class of work.

The average analyses of the products from the belt which are surprisingly uniform from month to month, are shown in the following table.

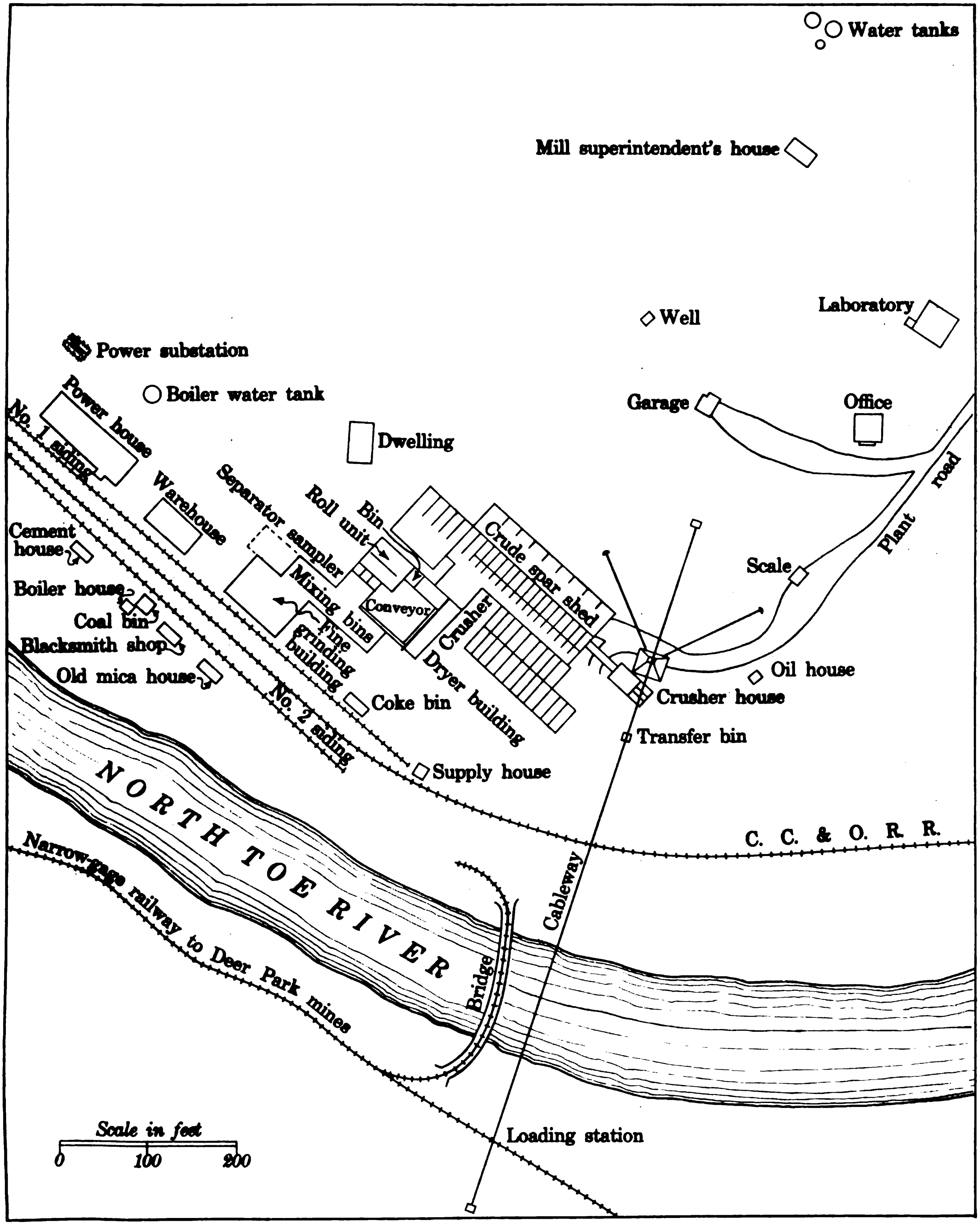


Figure 2.—Plan of Minpro plant

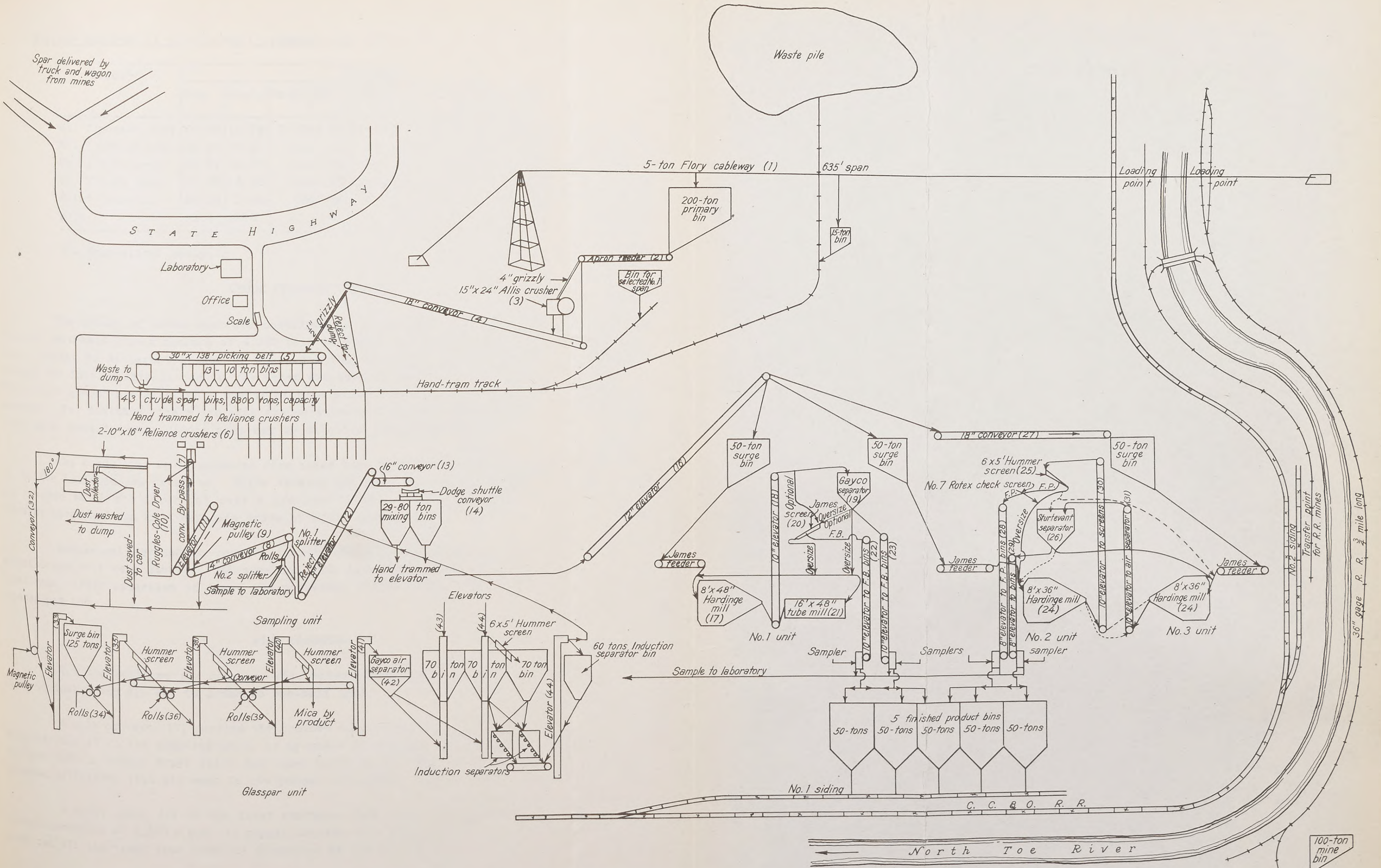


Figure 3.–Graphical flow sheet of Minpro plant

Average analyses of picking-belt products from crude spar from Deer Park mines

| Product | Per cent | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | $CaO$ | $MgO$ | $K_2O$ | $Na_2O$ | Loss | Total |
| No. 1 potash spar | 66.40 | 18.70 | 0.09 | 0.56 | Trace | 11.53 | 2.63 | 0.16 | 100.07 |
| No. 2 potash spar | 68.52 | 17.65 | .10 | .54 | .01 | 10.22 | 2.67 | .18 | 99.89 |
| No. 1 soda spar | 72.01 | 16.66 | .11 | 1.12 | .01 | 5.33 | 4.58 | .23 | 100.05 |
| No. 2 soda spar | 72.95 | 16.85 | .15 | 1.55 | Trace | 1.58 | 6.81 | .16 | 100.05 |
| Flint (quartz) | 98.29 | 1.08 | .03 | .36 | - | - | - | .05 | 99.81 |
| Mica[1] | 45.2 | 39.5 | - | - | - | 11.8 | - | 4.5 | 100.00 |

[1] - Theoretical analysis.

## CRUDE FELDSPAR STORAGE

The stocks of crude spar are contained in 43 bins and additional ground storage. They are increased from a minimum of 4,000 tons in summer to 8,000 tons in winter and represent at least 20 different grades of spar, varying from high potash and low soda content through the intermediate grades to the other extremes of high soda and low potash content. The various grades are allotted a number of bins proportional to the annual tonnage of each consumed. For instance, there are many grades which are allotted only one bin each. On the other hand, more commonly used grades may be allotted five or six bins.

The crude spar is transferred from these bins in wheelbarrows, each grade separately, to two Reliance jaw crushers. While forking the spar into the wheelbarrows, some fines are removed which are later put over a 1/4-inch screen. The undersize is wasted and the oversize saved and run as a separate grade of crude spar.

Mechanical devices to replace this hand-loading, screening, and transferring in wheelbarrows have been studied, but none has been found low enough in first cost to give a final cost, after reduction of fixed and operating charges, less than the present handling expense per ton.

## FINE CRUSHING

The two Reliance jaw crushers (6), which reduce the crude spar, have openings of 10 by 18 inches and are set to crush to one-half inch.

A belt conveyor (7) carries the crushed spar either to a 14-inch cross conveyor (8) which carries it to the sampling unit, or by means of a tripper on the first conveyor dumps the spar into a rotary dryer which has been found to so improve the product and increase grinding efficiency that all spar is now passed through it.

A motor which drives the first conveyor also runs a 3/4-kw. Northwestern direct-current generator at 1,300 r.p.m. to supply current to a high-duty magnetic pulley (9) which picks out all the tramp iron from the discharge of the conveyor.

About 0.2 pound of magnetic material is removed per ton of spar passing over the pulley. A large part of the metallic iron extracted is in the form of bolts, nuts, broken drill steel, nails, etc., although a small percentage of abraided iron and a little magnetite are removed.

## DRYING

The Ruggles-Coles rotary dryer (10), 70 inches in diameter and 30 feet long, has a 3/8-inch steel-plate shell and a silex refractory lining 4 1/2 inches thick. The dryer is of the direct-heat, counter-current type, and is rotated 5 1/2 times per minute by a 30-hp. motor. The furnace of the dryer has an auxiliary stack for starting and baffles to prevent cinders from getting into the drying cylinder. A stock grade of coke is used for fuel, costing $6.57 per ton delivered at the plant. The dryer has a capacity output of 10 tons per hour of dried spar containing less than one-half of 1 per cent of moisture from a feed through a 3/4-inch ring and containing 8 per cent moisture. With the average moisture content in the feed, 17 pounds of coke are required to dry a ton of feldspar.

In lining the dryer, ten rows of silex brick were placed on end to form lifters to cascade the feldspar through the hot furnace gases. These lifters have been effective in lowering fuel requirements and increasing the capacity of the dryer.

A No. 55 Clarage exhaust fan pulls the air against the flow of spar and in so doing extracts practically all of the minus 40-mesh material. These fines contain considerable mica, clay, and other impurities, and in removing them an improvement is made in the quality of the finished product that more than offsets the cost of drying. The dust from the dryers is collected in a cyclone-type, galvanized-iron, dust collector, 8 feet in diameter.

The discharge from the dryer falls into the boot of a bucket elevator (11) and is returned to the head end of the first-mentioned 14-inch conveyor, which discharges it over the magnetic pulley to a 14-inch cross conveyor by which it is carried to the sampling unit; or the discharge of the bucket elevator may be by-passed to the granular glasspar unit, which is described later.

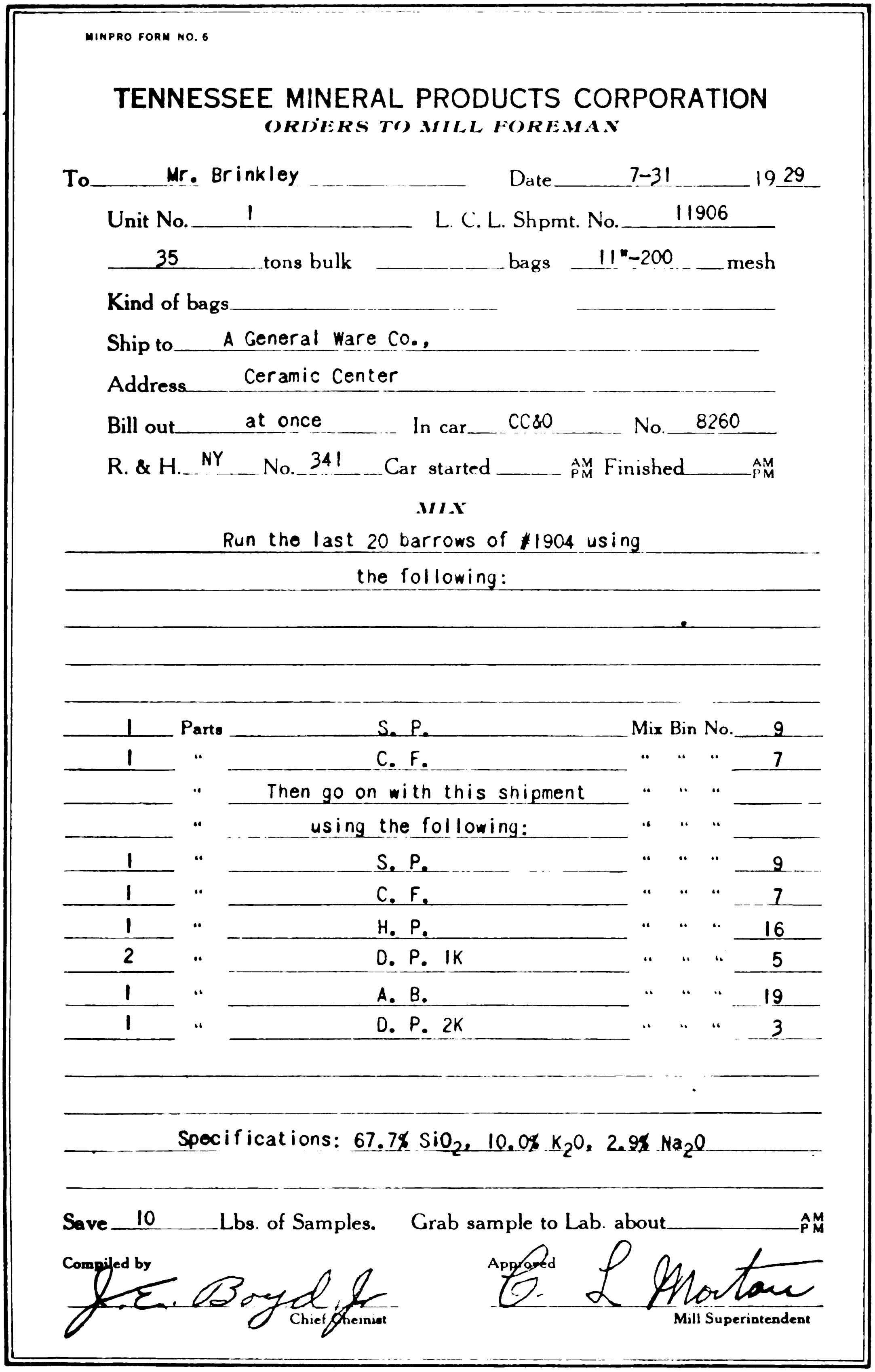
## SAMPLING UNIT

The sampling unit receives all spar from the crushers and dryer and from the granular glasspar unit. A swinging chute actuated by a revolving cam removes 2 per cent of the feed and passes it to a set of 12 by 12 inch Sturtevant rolls crushing to 8 mesh. Under the rolls is another sampler of similar design which removes 5 per cent of the discharge from the rolls. The resulting sample is 5 per cent of 2 per cent or 1 pound out of every 1,000 pounds entering the sampler.

The reject from the sampler, constituting 99.9 per cent of the feed, is raised by a bucket elevator (12) to a cross conveyor (13) which feeds a shuttle conveyor (14) mounted on a track over the mixing bins. This conveyor is reversible so that it can load any one of the 29 mixing bins beneath it.

All machines in the sampling unit are driven by a 20-hp. motor (15) from jack shafts.

Each grade of crude spar is run to the crushers separately and passes through the dryer and sampling unit to a separate mixing bin. As the capacity of each mixing bin is 80



MINPRO FORM NO. 6

TENNESSEE MINERAL PRODUCTS CORPORATION

*ORDERS TO MILL FOREMAN*

To Mr. Brinkley Date 7-31 1929

Unit No. 1 L. C. L. Shpmt. No. 11906

35 tons bulk bags 11"-200 mesh

Kind of bags

Ship to A General Ware Co.,

Address Ceramic Center

Bill out at once In car CC&O No. 8260

R. & H. NY No. 341 Car started AM PM Finished AM PM

*MIX*

Run the last 20 barrows of #1904 using

the following:

| | | | | |
|---|---|---|---|---|
| 1 | Parts | S. P. | Mix Bin No. | 9 |
| 1 | " | C. F. | " " " | 7 |
| | " | Then go on with this shipment | " " " | |
| | " | using the following: | " " " | |
| 1 | " | S. P. | " " " | 9 |
| 1 | " | C. F. | " " " | 7 |
| 1 | " | H. P. | " " " | 16 |
| 2 | " | D. P. 1K | " " " | 5 |
| 1 | " | A. B. | " " " | 19 |
| 1 | " | D. P. 2K | " " " | 3 |

Specifications: 67.7% $SiO_2$, 10.0% $K_2O$, 2.9% $Na_2O$

Save 10 Lbs. of Samples. Grab sample to Lab. about AM PM

Compiled by J. E. Boyd Jr. Chief Chemist

Approved C. L. Morton Mill Superintendent

Figure 4.- Order to mill foreman giving feldspar mix

tons, a 160-pound sample (1 pound from each 1,000 pounds) represents a full bin. Smaller lots down to 30 tons are often handled, resulting, of course, in a proportionally smaller sample. All samples are sorted and split down by standard methods and sent to the laboratory for complete chemical analysis. No spar from a mixing bin is withdrawn until its analysis is reported.

The 29 mixing bins supply an intermediate storage of 1,700 to 2,300 tons of crushed material in 29 separate lots which have been analyzed and are ready for fine grinding.

When an order for spar is received it is sent to the laboratory, where a mix calculated from the analyses of the spar in the mixing bins is made to fit the customer's specifications. An order (fig. 4) is then issued by the chief chemist to the mill foreman with the approval of the mill superintendent, showing the number of barrows to be drawn from each bin to make up the shipment. These barrows, containing 330 pounds each, are drawn in rotation as indicated on the order and dumped into the boot of an elevator (16) which empties into the 50-ton surge bin of the particular fine-grinding unit in which the lot is to be ground.

## FINE GRINDING

The fine-grinding department consists of three Hardinge-mill units, each fed from a 50-ton surge bin by James automatic-belt feeders. Unit 1 has an 8-foot by 48-inch Hardinge mill (17), the discharge from which is lifted by an elevator (18) either to a Gayco air separator (19) or a James vibrating screen (20), according to whether the product being prepared is fine (120 to 250 mesh) or coarse (20 mesh). If a product of intermediate size (40 to 100 mesh) is being made, the fines are first removed by the Gayco separator and the coarse material is then transferred to the screen where the final sizing is accomplished.

A tube mill (2) is operated for fine grinding in connection with unit 1. This mill receives about half the oversize from the Gayco separator and reduces it with less power than if the same grinding were done in the conical mill. The other half of the oversize is returned to the Hardinge mill. The use of the tube mill increases the plant capacity about 8 per cent.

Finished products from the screen and separator are lifted by elevators (22 and 23) to the top of the plant, where automatic samplers similar to those in the sample unit take a final sample of the finished product, which is chuted into any one of five finished-product bins, each of 50-ton capacity.

Fine-grinding units 2 and 3 are similar to unit 1 except that each of the Hardinge mills (24) is smaller, being 8 feet by 36 inches, and a double "Hum-mer" screen (25) is used in conjunction with a Sturtevant air separator (26). The conveyor (27) and elevators (28 to 31) in these units are described under "Details of Equipment," page 17.

All the chutes and feeding mechanisms in the fine-grinding department are lined with silex or rubber. The Hardinge mills are silex lined, use flint pebbles as the grinding medium, and make from 27 to 28 revolutions per minute.

The samples of finished products that are taken by the automatic samplers are sent to the laboratory and checked against the calculated analyses. A 2-ounce sample of every shipment is kept at the laboratory as a permanent record. Samples of products for which there is a steady demand from prospective customers are stored in the warehouse adjoining the plant.

From this description and the flow sheet (fig. 3), it will be seen that the design of the fine-grinding department provides great flexibility of operation so as to permit maxmum use of the equipment and gives a large capacity to handle rush orders.

## NEUTRALIZATION OF MIXES

In any continuous grinding process where lots of material of different analyses are ground consecutively, the material in the mill must be entirely ground out or a neutralizer added either between lots or before the grinding of the lot in the mill is completed, in order that it and the following lot shall each be of the desired analysis.

It is impracticable to run a Hardinge mill or any similar type of pebble mill until the material which it has been grinding is completely discharged; first, because it would take several hours to clear the mill, and second, because as the material being pulverized runs out of the mill, it leaves the pebbles to rattle against each other so that they would soon be ground down and broken to pieces, resulting in contamination of the product and loss of the pebbles themselves. Another way to clear the mill would be to dump the charge as in batch grinding, but if this were done, the advantages of continuous grinding would be lost.

Neutralization is therefore the only practical means of establishing uniformity of analysis in each lot and maintaining economy of operation. It may be effected in two ways; one, which we will call Method A, is to begin adding the neutralizer at some point before the entire tonnage for the lot already in the mill has been fed, the neutralizer, of course, being of such composition that when added in a calculated proportion to the charge in the mill, it will give the analysis required for the following lot. Method B is to feed the entire tonnage required for the first lot and immediately start feeding the neutralizer until a sufficient quantity of it is in the circuit to completely change the analysis of the first lot to the analysis desired for the second lot. At the point where this complete neutralization takes place, the regular feed for the second shipment is begun. In Method A the portions of the neutralizer absorbed by the preceding and following lots, respectively, affect the analyses of the two lots because they become an integral part of each and they must be allowed for in calculating the original mixtures for the two lots. In Method B the neutralizer is entirely removed, not going into either lot but being bagged and stored for future use.

Method A can therefore be used only for bulk shipments where the difference in the analyses of consecutive lots is not great. Correspondingly, Method B is used where there are wider differences in the analyses of the lots involved or for bag shipments where there is no opportunity to mix the neutralizer uniformly through the entire tonnage of the shipment.

The quantity of material in the grinding circuit is of course a determinant of the quantity of neutralizer which must be added to make the necessary change in analysis and is obviously entirely dependent upon the size of the grinding equipment. In order to determine the quantity of neutralizer that must be added to each of the fine-grinding units at the Minpro Plant, a definite change in the feed to each of the fine-grinding units was made, and

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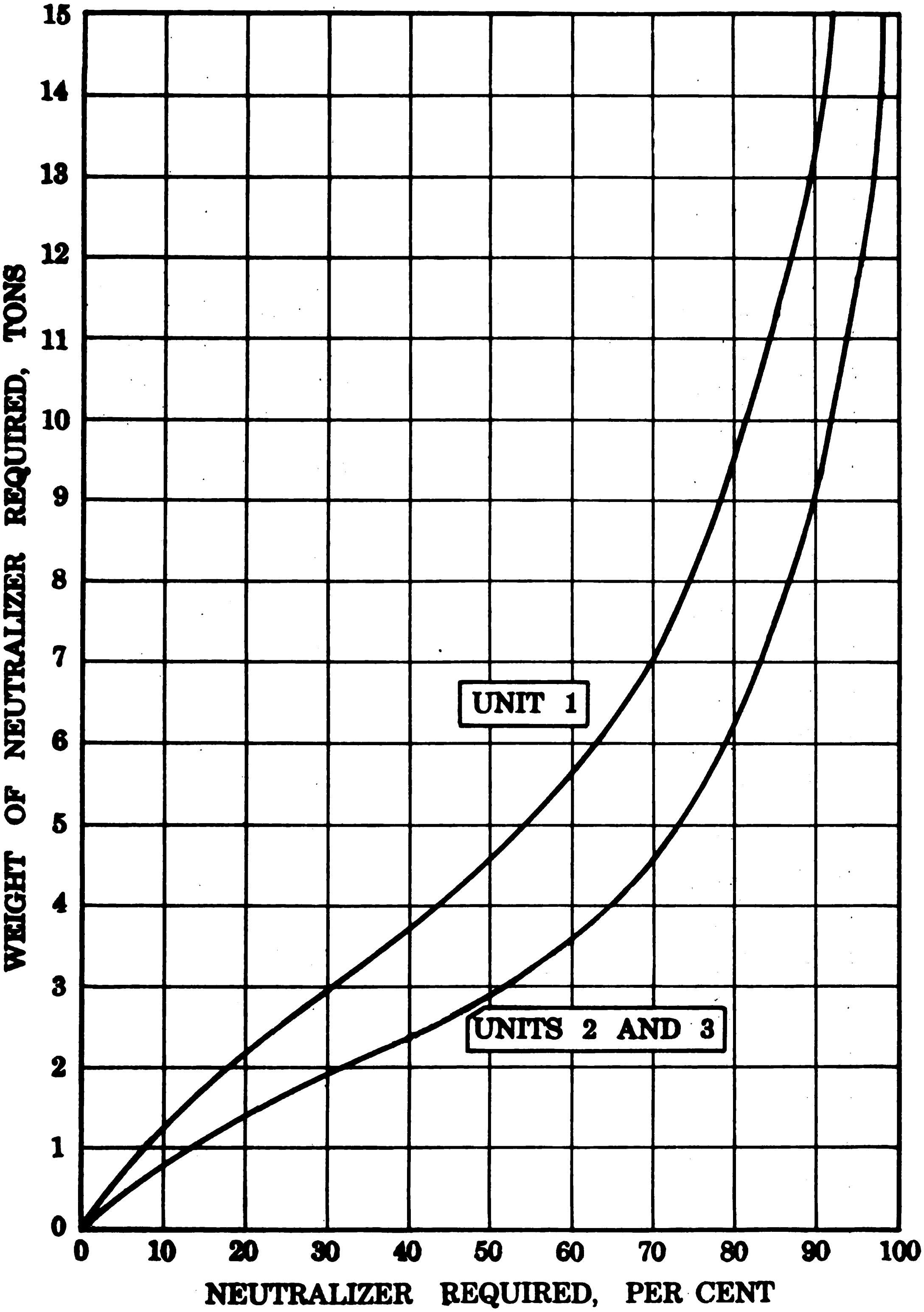
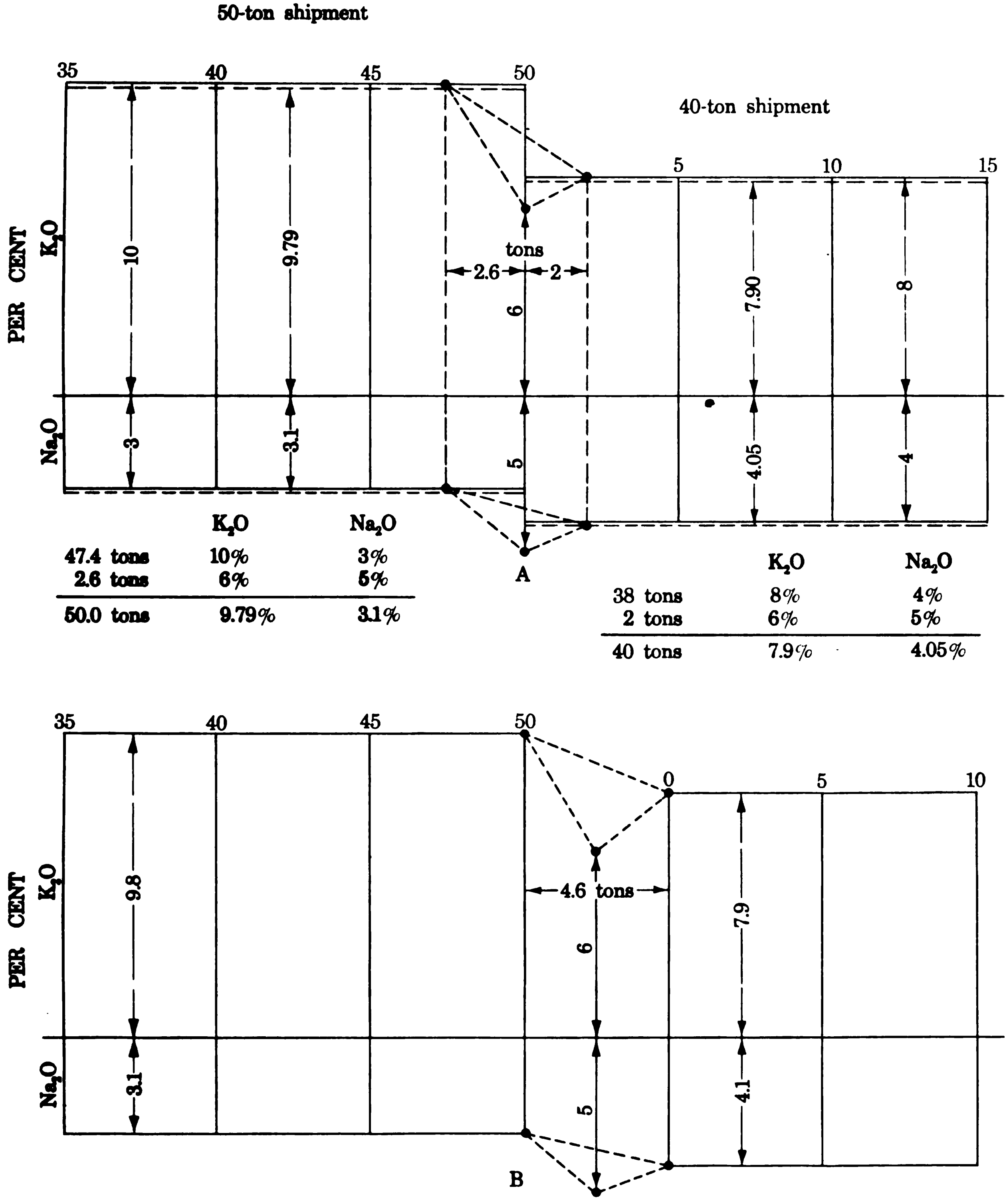


**Figure 5.**—Neutralization curves, showing weight and percentage of neutralizer required



| | $K_2O$ | $Na_2O$ |
|---|---|---|
| 47.4 tons | 10% | 3% |
| 2.6 tons | 6% | 5% |
| 50.0 tons | 9.79% | 3.1% |

| | $K_2O$ | $Na_2O$ |
|---|---|---|
| 38 tons | 8% | 4% |
| 2 tons | 6% | 5% |
| 40 tons | 7.9% | 4.05% |

**Figure 6.**—Diagrams showing two methods of changing mixes (neutralizing): A, where consecutive lots vary little in analysis; B, where consecutive lots vary considerably in analysis

samples of the product, taken at 15-minute intervals, were analyzed, and the results plotted to give curves (fig. 5) showing how many tons of neutralizer must be added to obtain the analysis required for a new lot in each of the Hardinge-mill units.

Simple illustrations will show how the two methods of neutralization are used and how the quantity of neutralizer required is calculated.

Suppose we have a 50-ton bulk shipment with specifications requiring slightly under 10 per cent potash and slightly over 3 per cent soda followed by a 40-ton bulk shipment with specifications just under 8 per cent potash and 4 per cent or slightly higher soda. Assuming that we have a spar containing 6 per cent potash and 5 per cent soda suitable for making the change in the mixture, it is apparent that an equal quantity of this neutralizer added to any portion of the 50-ton shipment will give the analysis required for the 40-ton shipment. Referring to the neutralization chart, Figure 5, and running up the line which represents 50 per cent to the curve for unit 1, we find this line intersects the curve at 4.6 tons. This, therefore, is the quantity of neutralizer that must be used to make the desired change. The neutralizer will be divided between the two shipments approximately in the proportion of their weights by adding 2.6 tons of it to the 50-ton shipment and 2 tons of it to the 40-ton shipment. We will therefore feed 47.4 tons of the 50-ton shipment, immediately following with 2.6 tons of the neutralizer; the 50-ton shipment will then be completed, and the discharge of finished product will be changed to the bin which is to receive the 40-ton shipment. There will be no interruption of the feed or grinding at all. After 2 more tons of the neutralizer are fed, completing the 4.6 tons required, the regular feed for the 40-ton shipment is commenced.

The resulting analysis of the 50-ton shipment will be 9.79 per cent of potash and 3.10 per cent of soda. and of the 40-ton shipment 7.90 per cent of potash and 4.05 per cent of soda.

A graphic representation of the effect on the potash and soda content of the two lots in neutralizing by these two methods is shown in Figure 6. Other constituents are affected similarly.

Since a bulk shipment is loaded in horizontal layers throughout the length of a box car and in addition is fairly well mixed in passing through the elevators and bins, the neutralizer added at the end and beginning of the respective shipments will be thoroughly distributed through the two cars in which the shipments are made.

In Method B, none of the neutralizer will appear in either shipment, so that the original mixtures for them can be calculated without allowing for the neutralizer which when ground is removed and stored until an order is received for material of the same screen size and analysis to which it can be added.

## GRANULAR GLASSPAR UNIT

Inasmuch as a crushed spar, free from fines, is desired by the glass industry, crushing in the glasspar unit is done with rolls instead of pebble mills, which are universally used in the ordinary grinding of feldspar.

The discharge from the Reliance crushers (6), which are set to crush to about 1/2-inch size or from the dryer (10) is transferred by a conveyor (32) having a magnetic head pulley to the boot of a bucket elevator (33) discharging into a 125-ton surge bin that supplies the feed to the glasspar unit.

From the surge bin the ore is fed by chute to Sturtevant rolls (34) set three-eighths inch apart. The discharge from the rolls is elevated (35) to a double-deck "Hum-mer" screen with 1/4-inch and 20-mesh screens. Oversize on the coarser screen is returned to the rolls; the intermediate size goes to a second set of Sturtevant rolls (36) set three-sixteenths inch apart; and the undersize through 20 mesh, which is now finished as to maximum size, is carried by a belt conveyor (37) and elevator (41) to a Gayco air separator (42) for removal of fines. The discharge from the second rolls (36) is elevated (38) to a second double-deck "Hum-mer" screen with 8 and 20 mesh screens. The oversize from the coarser screen is returned to the rolls, the intermediate size goes to a third set of Sturtevant rolls (39) set close, and the undersize through 20 mesh proceeds to the Gayco separator.

The discharge from the third set of rolls is elevated (40) to a third double-deck "Hum-mer" screen with 10 and 20 mesh decks. Oversize on the 10-mesh screen, consisting principally of mica, is removed as a by-product, the intermediate size is returned to the rolls, and the undersize through 20 mesh joins the similar products from the preceding screens on their way to the Gayco separator.

Although the rolls produce only a small fraction of the fines which are made by the ordinary process of grinding in pebble mills, there is still a little minus 140-mesh material in the undersize through 20 mesh. To remove this, the product is put through the Gayco separator (42) and the extracted fines are elevated (43) to a separate bin for use with similar products from the fine-grinding department.

The oversize from the Gayco separator is elevated (44) to a "Hum-mer" screen, which separates it into two sizes; minus 20 plus 40 mesh, and minus 40 plus 140 mesh. These two sizes are held in 70-ton feed bins, from which they run over two Johnson induction separators one size going to each machine.

The Johnson separators are of the electromagnetic induction type. Each machine has two large coils, an upper coil with three pole pieces at each end, and a lower coil with two pole pieces at each end. A laminated rotor, 30 inches long, revolves under each of these pole pieces. A special device feeds a thin uniform stream of the sized spar over the length of each rotor. As the material passes from one rotor to the next, all magnetic particles are deflected by the rotors, permitting the feldspar to continue on through five successive cleaning treatments. Each rotor removes a portion of the contaminating minerals, the more highly magnetic being removed by the upper rotors and the feebly magnetic by the lower rotors.

The strength of the magnetic field developed by the Johnson induction separator is phenominal, and as the separation depends on the deflection of magnetic particles in falling rather than on lifting, astonishing results are obtained, in that minerals even with traces of iron are removed. For example, muscovite without visible iron stain is removed from the spar which, prepared by this method, consistently contains less than 0.06 per cent of iron or about one-half of the usual maximum specification for this type of spar.

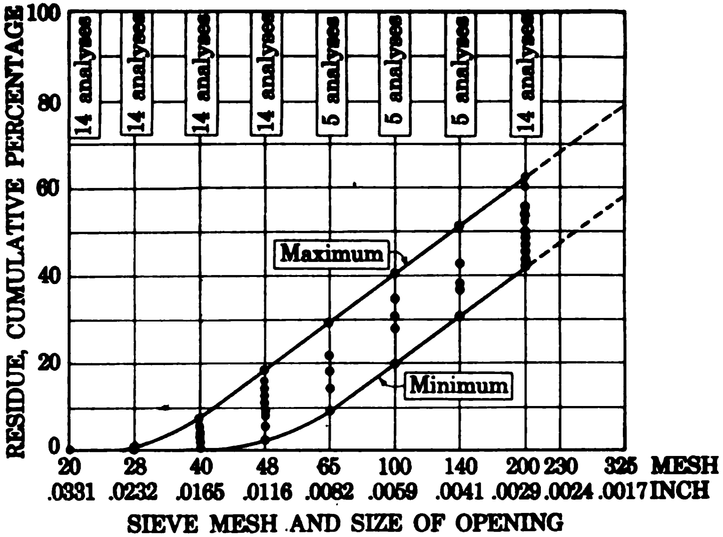


Figure 7.—Screen analyses of Hardinge mill-Hummer screen 20-mesh product

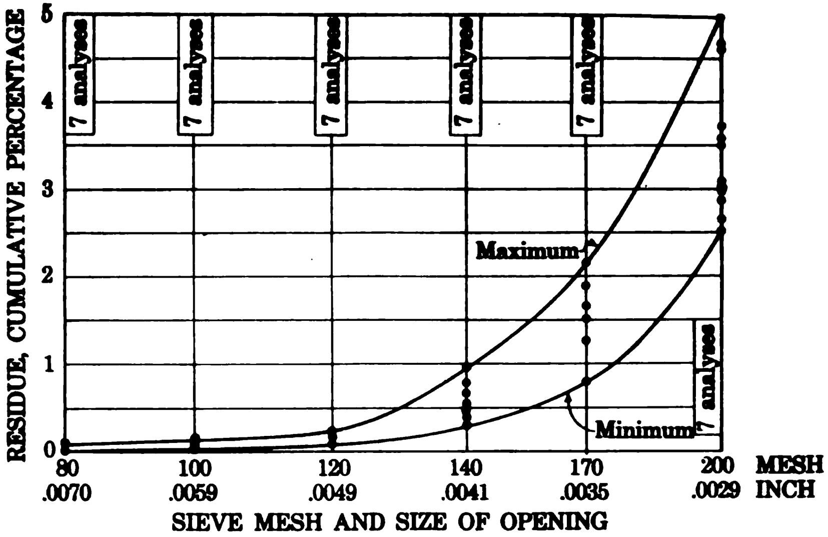


Figure 8.—Screen analyses of Hardinge mill-Gayco separator 140-mesh product

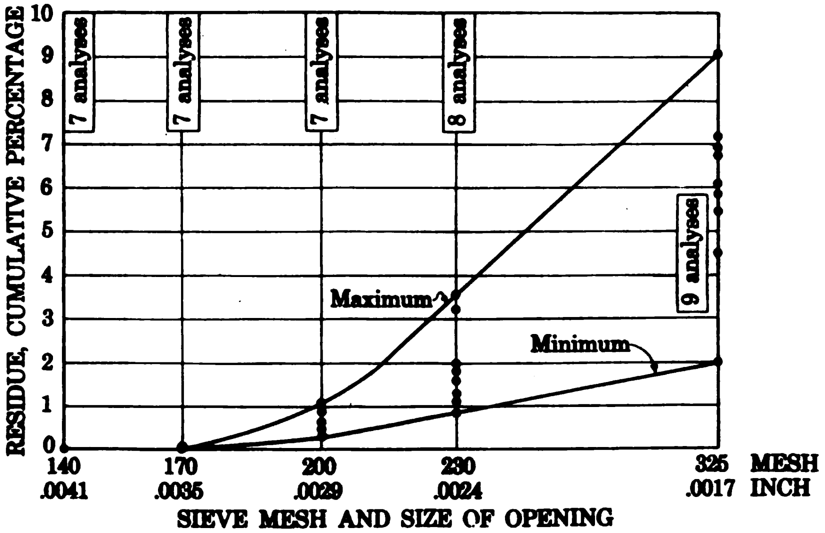


Figure 9.—Screen analyses of Hardinge mill-Gayco separator 200-mesh product

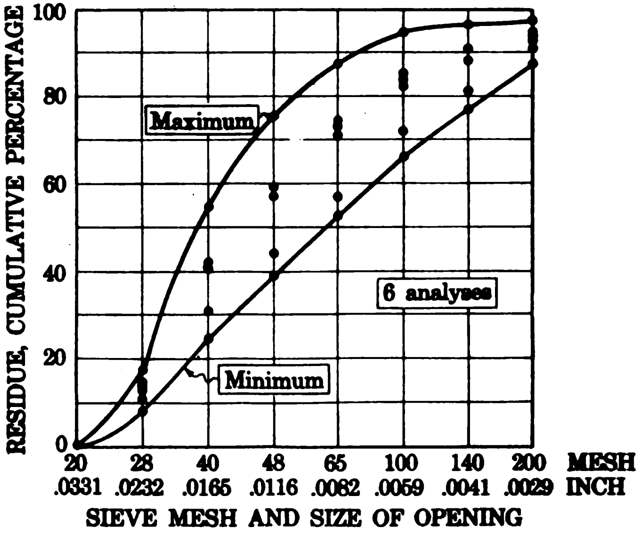


Figure 10.—Screen analyses of Glasspar-unit 20-mesh product

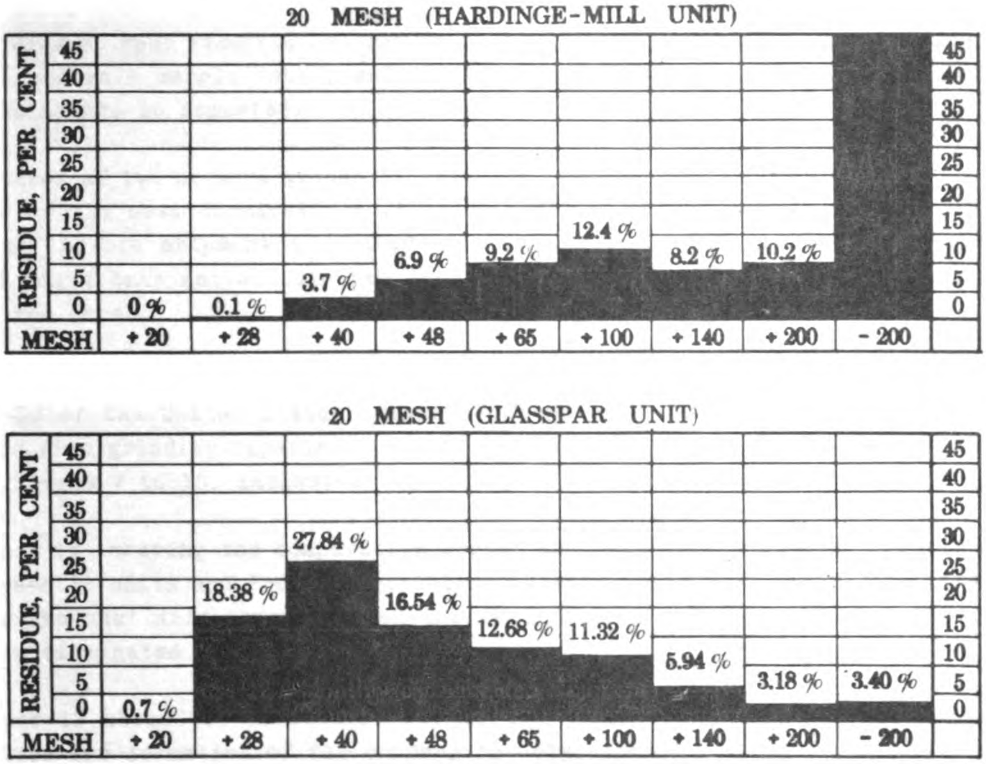


**Figure 11.** – Comparative screen analysis of 20-mesh product from Hardinge-mill and Glasspar units

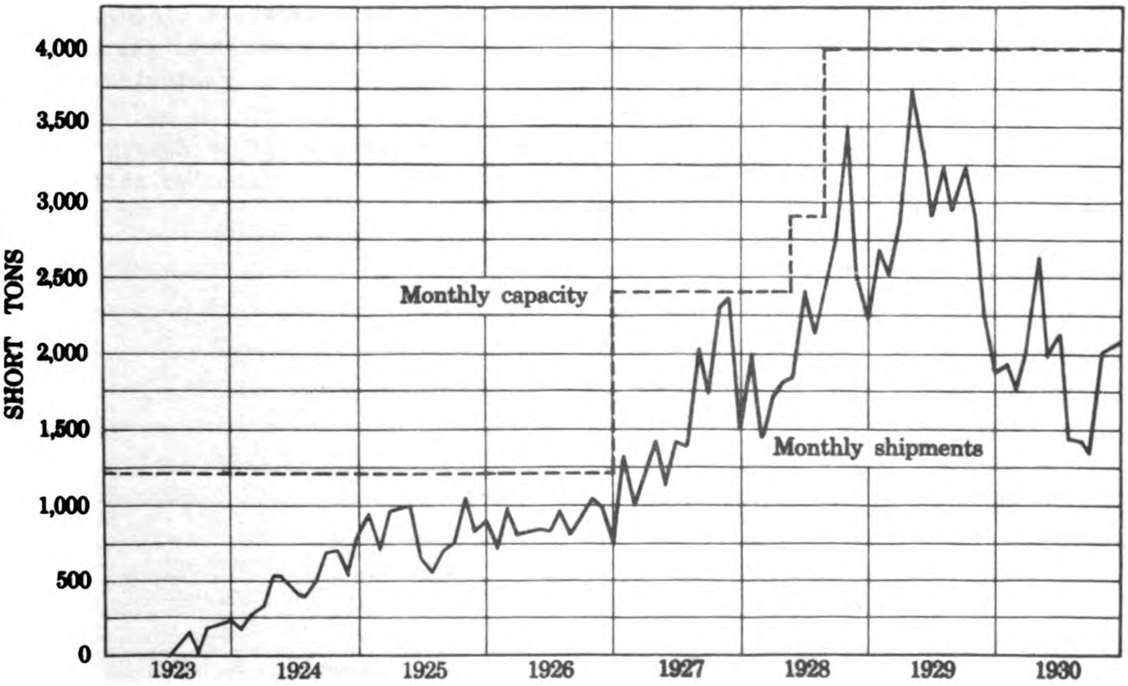


**Figure 12.** – Monthly capacity and shipments of ground feldspar Tennessee Mineral Products Corporation

The cleaned spar from the Johnson separators is elevated (44) to the sampling unit, a mechanically accurate sample taken, and the material stored in the mixing bins until the analysis of the sample is reported.

Mixtures of two or more grades of granular glasspar are made to meet the customer's specifications by the same chemically controlled methods as the company uses in making its other products. Before shipment the mixed material is carefully rescreened to remove any oversize which might have gotten into it. From the check screen the granular glasspar goes directly into the cars.

Typical screen analyses, according to the classification specified by Commercial Standard CS23-30 of the United States Bureau of Standards, of 20, 140, and 200 mesh spars produced in the fine grinding department and of 20-mesh spar from the granular glasspar unit are given in figures 7 to 10, inclusive.

Figure 11, showing the comparative screen analysis of the 20-mesh product from one of the Hardinge-mill units and from the granular-glasspar unit is of particular interest, as it illustrates the vast difference between the two products and shows to what an extent the fines have been eliminated from the glasspar.

Figure 12 shows the rated capacity of the Minpro plant and monthly shipments of ground spar since the formation of the company in July, 1923.

To consumers familiar only with the simple flow sheet of the average feldspar grinding plant, that of the Tennessee Mineral Products Corporation (fig. 3) may seem unnecessarily expensive and complicated. Experience, however, has proved that every step in the process is necessary for the production of uniform products of known analysis. The special features of the plant are segregation of individual crude spars which is continued through intermediate storage, mining of spars on the basis of chemical analysis, and neutralization during continuous grinding to produce ground spars to meet the customer's specifications of analysis.

The growth of the company's business is testimony of the accuracy and efficiency of its production methods.

## ANALYSES OF MINPRO SPARS ARRANGED ACCORDING TO COMMERCIAL STANDARD CLASSIFICATION

### Enamel and Body Feldspars

| Grade | | Per cent | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $K_2O$ | $Na_2O$ | Loss |
| 67-31 | A | 67.0 | 19.0 | 0.1 | 0.8 | Trace | 9.1 | 3.7 | 0.3 |
| 67-31 | B | 67.5 | 18.8 | .1 | .8 | do. | 8.9 | 3.8 | .3 |
| 67-31 | C | 67.5 | 18.7 | .1 | .7 | do. | 9.3 | 3.4 | .3 |
| 67-41 | A | 66.6 | 18.9 | .1 | .6 | do. | 10.4 | 3.0 | .3 |
| 67-41 | B | 66.7 | 18.9 | .1 | .6 | do. | 10.9 | 2.6 | .3 |
| 67-41 | C | 67.0 | 18.9 | .1 | .7 | do. | 10.0 | 3.2 | .3 |
| 67-41 | D | 67.0 | 18.7 | .1 | .6 | do. | 10.2 | 3.0 | .3 |
| 67-41 | E | 67.0 | 18.6 | .1 | .6 | do. | 10.7 | 2.6 | .3 |
| 67-41 | F | 67.5 | 18.6 | .1 | .7 | do. | 9.7 | 3.2 | .3 |
| 67-41 | G | 67.5 | 18.5 | .1 | .6 | do. | 10.0 | 3.0 | .3 |
| 67-41 | H | 67.5 | 18.5 | .1 | .5 | do. | 10.6 | 2.5 | .3 |
| 67-41 | I | 67.7 | 18.3 | .1 | .5 | do. | 10.3 | 2.9 | .3 |
| 67-51 | A | 66.6 | 18.7 | .1 | .4 | do. | 11.7 | 2.0 | .3 |
| 67-51 | B | 67.0 | 18.5 | .1 | .4 | do. | 11.6 | 2.0 | .3 |
| 67-51 | C | 67.5 | 18.3 | .1 | .4 | do. | 11.5 | 2.1 | .3 |
| 69-31 | A | 68.0 | 18.2 | .1 | .8 | do. | 8.7 | 3.8 | .3 |
| 69-31 | B | 68.0 | 18.3 | .1 | .7 | do. | 9.0 | 3.6 | .3 |
| 69-31 | C | 68.0 | 18.2 | .1 | .7 | do. | 9.5 | 3.4 | .2 |
| 69-31 | D | 68.5 | 18.3 | .1 | .8 | do. | 8.3 | 3.8 | .3 |
| 69-31 | E | 68.5 | 17.9 | .1 | .9 | do. | 8.7 | 3.5 | .3 |
| 69-31 | F | 68.5 | 18.0 | .1 | .8 | do. | 8.9 | 3.3 | .3 |
| 69-31 | G | 69.0 | 17.9 | .1 | .8 | do. | 8.0 | 3.8 | .3 |
| 69-31 | H | 69.0 | 17.7 | .1 | .7 | do. | 8.5 | 3.5 | .3 |
| 69-31 | I | 69.0 | 17.7 | .1 | .7 | do. | 9.1 | 3.2 | .3 |
| 69-31 | J | 69.5 | 17.7 | .1 | .8 | do. | 7.8 | 3.8 | .3 |
| 69-31 | K | 69.5 | 17.6 | .1 | .7 | do. | 8.4 | 3.4 | .3 |
| 69-31 | L | 69.5 | 17.6 | .1 | .6 | do. | 8.9 | 3.2 | .3 |
| 69-41 | A | 68.0 | 18.3 | .1 | .7 | do. | 9.6 | 3.2 | .3 |
| 69-41 | B | 68.0 | 18.1 | .1 | .6 | do. | 10.0 | 2.8 | .3 |
| 69-41 | C | 68.0 | 18.1 | .1 | .6 | do. | 10.4 | 2.5 | .3 |
| 69-41 | D | 68.5 | 18.0 | .1 | .7 | do. | 9.4 | 3.1 | .3 |
| 69-41 | E | 68.5 | 18.0 | .1 | .6 | do. | 9.7 | 3.0 | .3 |
| 69-41 | F | 68.5 | 17.9 | .1 | .4 | do. | 10.2 | 2.5 | .3 |
| 69-41 | G | 69.0 | 17.7 | .1 | .6 | do. | 9.2 | 3.0 | .3 |
| 69-41 | H | 69.0 | 17.7 | .1 | .6 | do. | 9.6 | 2.8 | .3 |
| 69-41 | I | 69.0 | 17.6 | .1 | .5 | do. | 9.9 | 2.5 | .3 |
| 69-41 | J | 69.5 | 17.5 | .1 | .6 | do. | 9.0 | 2.8 | .3 |
| 69-41 | K | 69.5 | 17.3 | .1 | .5 | do. | 9.6 | 2.6 | .3 |

## ANALYSES OF MINPRO SPARS ARRANGED ACCORDING TO COMMERCIAL STANDARD CLASSIFICATION

### Enamel and Body Feldspars - (Continued)

| | Per cent | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Grade | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $K_2O$ | $Na_2O$ | Loss |
| 69-51 A | 68.0 | 18.0 | .1 | .4 | Trace | 11.2 | 2.0 | .3 |
| 69-51 B | 68.5 | 17.7 | .1 | .4 | do. | 11.0 | 2.0 | .3 |
| 69-51 C | 69.0 | 17.5 | .1 | .4 | do. | 10.6 | 2.1 | .3 |
| 69-51 D | 69.5 | 17.2 | .1 | .4 | do. | 10.4 | 1.9 | .3 |
| 71-31 A | 70.0 | 17.5 | 0.1 | 0.9 | do. | 7.5 | 3.7 | 0.3 |
| 71-31 B | 70.0 | 17.3 | .1 | .8 | do. | 8.1 | 3.4 | .3 |
| 71-31 C | 70.0 | 17.1 | .1 | .6 | do. | 8.7 | 2.9 | .3 |
| 71-31 D | 70.5 | 17.1 | .1 | .9 | do. | 7.2 | 3.7 | .3 |
| 71-31 E | 70.5 | 17.0 | .1 | .9 | do. | 7.8 | 3.4 | .3 |
| 71-31 F | 70.5 | 17.0 | .1 | .6 | do. | 8.4 | 3.0 | .3 |
| 71-31 G | 71.0 | 16.7 | .1 | .9 | do. | 7.1 | 3.7 | .3 |
| 71-31 H | 71.0 | 16.9 | .1 | .8 | do. | 7.4 | 3.5 | .3 |
| 71-31 I | 71.0 | 16.8 | .1 | .6 | do. | 8.1 | 3.1 | .3 |
| 71-31 J | 71.5 | 16.6 | .1 | .8 | do. | 7.2 | 3.6 | .3 |
| 71-31 K | 71.5 | 16.5 | .1 | .7 | do. | 8.0 | 3.0 | .3 |
| 71-41 A | 70.0 | 17.3 | .1 | .6 | do. | 8.8 | 2.8 | .3 |
| 71-41 B | 70.0 | 17.2 | .1 | .5 | do. | 9.1 | 2.7 | .3 |
| 71-41 C | 70.0 | 17.2 | .1 | .4 | do. | 9.5 | 2.5 | .3 |
| 71-41 D | 70.5 | 17.0 | .1 | .5 | do. | 8.6 | 2.8 | .3 |
| 71-41 E | 70.5 | 17.0 | .1 | .5 | do. | 8.9 | 2.7 | .3 |
| 71-41 F | 70.5 | 16.8 | .1 | .4 | do. | 9.4 | 2.5 | .3 |
| 71-41 G | 71.0 | 16.7 | .1 | .5 | do. | 8.6 | 2.7 | .3 |
| 71-41 H | 71.0 | 16.6 | .1 | .4 | do. | 9.0 | 2.5 | .3 |
| 71-41 I | 71.5 | 16.5 | .1 | .5 | do. | 8.6 | 2.5 | .3 |
| 71-41 J | 71.5 | 16.4 | .1 | .4 | do. | 9.0 | 2.4 | .3 |
| 71-51 A | 70.0 | 17.0 | .1 | .5 | do. | 10.1 | 2.0 | .3 |
| 73-31 A | 72.0 | 16.2 | .1 | .7 | do. | 8.0 | 3.0 | .3 |
| 73-31 B | 72.5 | 15.9 | .1 | .7 | do. | 7.7 | 3.2 | .3 |
| 73-31 C | 73.0 | 15.7 | .1 | .6 | do. | 7.7 | 3.0 | .3 |
| 73-31 D | 73.5 | 15.5 | .1 | .5 | do. | 7.5 | 2.8 | .3 |
| 73-41 A | 72.0 | 16.1 | .1 | .4 | do. | 8.4 | 2.5 | .3 |
| 73-41 B | 72.5 | 15.9 | .1 | .4 | do. | 8.1 | 2.4 | .3 |
| 73-41 C | 73.0 | 15.8 | .1 | .4 | do. | 8.0 | 2.4 | .3 |

# ANALYSES OF MINPRO SPARS ARRANGED ACCORDING TO COMMERCIAL STANDARD CLASSIFICATION

## Glaze Feldspars

| Grade | | Per cent | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $K_2O$ | $Na_2O$ | Loss |
| 4 | A | 67.6 | 18.3 | .1 | 1.0 | Trace | 8.6 | 4.1 | .3 |
| 4 | B | 68.5 | 18.2 | .1 | .8 | do. | 8.3 | 4.1 | .3 |
| 4 | C | 69.4 | 17.9 | .1 | .7 | do. | 7.5 | 4.2 | .3 |
| 4 | D | 68.0 | 18.4 | .1 | 1.0 | do. | 7.6 | 4.5 | .3 |
| 5 | A | 69.6 | 18.1 | .1 | .9 | do. | 6.2 | 5.0 | .3 |
| 5 | B | 68.3 | 18.5 | .1 | 1.1 | do. | 6.5 | 5.0 | .3 |
| 5 | C | 68.6 | 18.6 | .1 | 1.2 | do. | 5.7 | 5.3 | .3 |
| 5 | D | 68.7 | 18.7 | .1 | 1.3 | do. | 5.1 | 5.8 | .3 |
| 6 | A | 69.5 | 18.6 | .1 | 1.4 | do. | 3.9 | 6.3 | .3 |
| 73-15-X | A | 73.5 | 15.5 | 0.1 | 0.5 | do. | 7.4 | 2.8 | 0.3 |
| 73-16-X | A | 72.0 | 16.2 | .1 | 1.0 | do. | 6.6 | 3.9 | .3 |
| 73-16-X | B | 72.0 | 16.0 | .1 | .7 | do. | 8.0 | 3.1 | .3 |
| 71-16-X | A | 71.7 | 16.5 | .1 | .5 | do. | 7.7 | 3.2 | .3 |
| 71-17-X | A | 70.5 | 17.0 | .1 | .5 | do. | 8.7 | 3.0 | .3 |
| 71-17-X | B | 70.0 | 17.5 | .1 | .9 | do. | 7.6 | 3.6 | .3 |
| 71-17-X | C | 70.5 | 17.5 | .1 | 1.3 | do. | 5.6 | 4.7 | .3 |
| 69-17-X | A | 69.3 | 17.5 | .1 | .8 | do. | 9.3 | 2.8 | .3 |
| 69-17-X | B | 69.4 | 17.5 | .1 | .5 | do. | 9.6 | 2.6 | .3 |
| 69-18-X | A | 69.3 | 18.0 | .1 | 1.0 | do. | 7.7 | 3.7 | .3 |
| 69-18-X | B | 68.7 | 18.5 | .1 | 1.1 | do. | 7.3 | 4.0 | .3 |
| 69-18-X | C | 68.3 | 18.5 | .1 | .8 | do. | 8.8 | 3.2 | .3 |
| 69-18-X | D | 69.8 | 18.0 | .1 | 1.2 | do. | 6.1 | 4.5 | .3 |
| 69-18-X | E | 67.6 | 18.1 | .1 | .4 | do. | 11.2 | 2.1 | .3 |
| 67-19-X | A | 67.1 | 19.0 | .1 | .8 | do. | 8.4 | 3.9 | .3 |
| 67-19-X | B | 66.5 | 19.5 | .1 | 1.1 | do. | 8.0 | 4.1 | .3 |
| 67-19-X | C | 68.5 | 19.2 | .1 | .8 | do. | 10.7 | 2.3 | .3 |
| 67-19-X | D | 68.0 | 19.5 | .1 | 1.9 | do. | 4.2 | 6.1 | .3 |
| 67-19-X | E | 66.6 | 19.1 | .1 | .7 | do. | 10.1 | 3.0 | .3 |

## DETAILS OF EQUIPMENT

The numbers of the following items refer to corresponding numbers on the graphical flow sheet (fig. 3).

1. Cable-way hoist, run by 70-hp., 3-phase, 60-cycle, 750-r.p.m., Westinghouse industion motor.

2. Forty-eight inch steel Stephens-Adamson apron feeder, 10 feet 6 inches between centers.

3. Driven by a 60-hp., 2,200-volt, 900-r.p.m., General Electric induction motor.

4. Eighteen-inch, inclined, 4-ply, rubber-belt conveyor, 70 feet long, powered by a 5-hp., 3-phase, 60-cycle, 2,200-volt, 1,200-r.p.m., General Electric induction motor.

5. Driven by a 5-hp., 3-phase, 60-cycle, 2,200-volt, 1,200-r.p.m., General Electric induction motor.

6. Driven by two 15-hp., 3-phase, 60-cycle, 220-volt, 900-r.p.m. Westinghouse induction motors.

7. Fourteen-inch, 4-ply, rubber-belt conveyor, 82 feet between centers, powered by a 3-hp., 3-phase, 60-cycle, 220-volt, 1,200-r.p.m., General Electric motor.

8. Driven from jack shaft by the dryer motor.

9. Twelve-inch diameter, 20-inch face.

10. Type L-10, driven by a 30-hp., 3-phase, 60-cycle, 2,500-volt, 900-r.p.m., General Electric motor.

11. Ten-inch, 6-ply, rubber-belt Dodge bucket elevator with 9 by 6 inch malleable-iron buckets spaced on 2-foot centers.

12. Eight-inch bucket elevator 22 feet between centers with 8 by 5 by 5½ inch malleable-iron buckets on 1-foot centers.

13. Sixteen-inch, 4-ply, rubber-belt conveyor, 16 feet between centers.

14. Reversible, 14-inch, 4-ply, rubber-belt Dodge shuttle conveyor 62 feet between centers.

15. Three-phase, 60-cycle, 220-volt, 900-r.p.m., General Electric induction motor.

16. Twelve-inch, 6-ply, rubber-belt elevator 44 feet 5 inches between centers with 12 by 6 by 6 1/4 inch malleable-iron buckets on 1-foot centers.

17. Hardinge mill, 8 feet by 48 inches, lined with 9,100 pounds of silex brick and charged with 12,800 pounds of 4-inch Danish flint pebbles. It is driven from a 100-hp.,

3-phase, 60-cycle, 2,200-volt, 485-r.p.m. Fairbanks-Morse induction motor by an Allis-Chalmers "Texrope" drive, 60-inch centers, and having nine 1 1/4 by 7/8 inch belts.

18. Ten-inch, 6-ply, rubber-belt elevator 68 feet between centers with 8 by 5 by 5 1/2 inch malleable-iron buckets on 12-inch centers, driven by a 3-hp., 220-volt, 1,200-r.p.m. Western Electric motor.

19. Fourteen-foot, model 26. type H, size 14, Gayco centrifugal air separator with a cone 7 feet 6 inches high and tapering from 10 feet 6 inches in diameter to 10 inches. It has a 1/8-inch steel shell and a 3/32-inch steel lining and is driven by a 20-hp., 220-volt, 900-r.p.m. General Electric induction motor.

20. James vibrating screen 3 by 6 feet, direct connected to a 1-hp., 3-phase, 60-cycle, 220-volt, 1,200-r.p.m. Continental Electric induction motor.

21. Smidth tube mill 4 by 16 feet, with 7/16-inch steel shell and 2 1/2-inch silex lining; load, 6,000 pounds of 2-inch flint pebbles; driven by a 25-hp., 3-phase, 60-cycle, 900-r.p.m. General Electric induction motor.

22 Ten-inch, 6-ply, rubber-belt elevator 37 feet between centers, with 8 by 5 by 5 1/2 inch malleable-iron buckets spaced on 12-inch centers, driven by a 3-hp., 220-volt, 1,200-r.p.m. Western Electric motor.

23. Ten-inch, 6-ply, rubber-belt elevator 54 feet between centers, with 8 by 5 by 5 1/2 inch malleable-iron buckets spaced on 12-inch centers, driven by a 3-hp., 220-volt, 1,200-r.p.m. General Electric motor.

24. Hardinge mill, 8 feet by 36 inches, lined with 8,125 pounds of silex brick, charged with 11,600 pounds of flint pebbles, and driven from a 75-hp., 3-phase, 60-cycle, 220-volt General Electric induction motor by an Allis-Chalmers "Texrope" drive with 42-inch centers and having eight 1 1/4 by 7/8 inch belts.

25. Tyler 6 by 5 foot, Type 31, "Hum-mer" vibrating screen equipped with type V16 electric vibrators.

26. Sturtevant 14-foot air separator, driven by a 30-hp., 2,200-volt, 900-r.p.m. General Electric induction motor.

27. Eighteen-inch, 4-ply, rubber-belt conveyor, 19 feet between centers, driven by a 5-hp., 220-volt, 1,200-r.p.m. General Electric motor.

28 and 29. Eight-inch, 5-ply, rubber-belt bucket elevators 64 feet 6 inches between centers, with malleable-iron buckets 6 by 4 by 4 1/2 inches spaced on 12-inch centers.

30. Ten-inch, 6-ply, rubber-belt bucket elevator, 80 feet between centers with malleable-iron buckets 8 by 5 by 5 1/2 inches spaced on 16-inch centers.

31. Ten-inch, 6-ply, rubber-belt bucket elevator, 67 feet between centers, with 8 by 5 by 5 1/2 inch malleable-iron buckets spaced on 14-inch centers.

32. Fourteen-inch, 4-ply, rubber-belt conveyor, 66 feet 10 inches between centers, powered by 3-hp., 3-phase, 60-cycle, 220-volt, 1,200-r.p.m. General Electric motor.

33. Ten-inch, 6-ply, rubber-belt bucket elevator, 48 feet 6 inches between centers with 8 by 5 by 5½ inch malleable-iron buckets spaced on 16-inch centers and powered by a 3-hp., 3-phase, 60-cycle, 220-volt, 1,200-r.p.m. General Electric motor.

34. Sturtevant balanced rolls, 22 by 14 inches, run at 165 r.p.m.

35. Eight-inch, 5-ply, rubber-belt bucket elevator, 33 feet 6 inches between centers with 7 by 4½ by 5 inch malleable-iron buckets spaced on 16-inch centers.

36. Sturtevant balanced rolls, 20 by 14 inches, making 195 r.p.m.

37. Fourteen-inch, 4-ply, rubber-belt conveyor 21 feet 6 inches between centers powered by a 3-hp., 3-phase, 60-cycle, 220-volt, 1,200-r.p.m. General Electric motor.

38. Same as 35.

39. Same as 36 except making 215 r.p.m.

40. Same as 35.

41. Eight-inch, 4-ply, rubber-belt bucket elevator 33 feet 6 inches between centers with 6 by 4 by 4½ inch buckets spaced on 16-inch centers.

42. Same as 19, except that the separator is Model 21.

Numbers 33 to 36, inclusive, and 39 to 42, inclusive, are powered by a 75-hp., 3-phase, 60-cycle, 2,200-volt, 690-r.p.m. General Electric induction motor which drives a jack shaft by means of a 16-inch, 6-ply, endless "Hyflex" rubber belt.

43. Eight-inch, 5-ply, rubber-belt bucket elevator, 26 feet between centers, with 6 by 4 by 4½ inch malleable-iron buckets spaced on 16-inch centers.

44. Same as 43 except 51 feet between centers.

Numbers 43 and 44 are powered by a 5-hp., 3-phase, 60-cycle, 220-volt, 1,150-r.p.m. General Electric induction motor driving through a jack shaft.

45. Eight-inch, 5-ply, rubber-belt bucket elevator, 50 feet between centers, with 6 by 4 by 4½ inch malleable-iron buckets spaced on 16-inch centers and powered by a 3-hp., 3-phase, 60-cycle, 1,200-r.p.m. General Electric induction motor.

Belt speeds on elevators are about 250 per minute; on conveyors, 175 to 180 per minute.

## Power

Power is purchased from the Carolina Power and Light Co. on a sliding scale contract under which costs range from 1.25 to 1.5 cents per kilowatt hour. Power is delivered to the plant transformers at 2,300 volts as 3-phase, 60-cycle current.

## COSTS

### MILLING COSTS, PER TON

Period covered——1929 Tons produced——34,108

| | | |
|---|---|---|
| Preliminary milling: | | |
| Crude-bin expense | $0.019 | |
| Tramming to Reliance crusher | .208 | |
| Fine crushing and conveying | .044 | |
| Drying | .123 | |
| Sampling and conveying | .032 | |
| Total milling cost to mixing bins | | $0.426 |
| Finishing: | | |
| Mixing-bin expense | $0.087 | |
| Fine grinding | 0.744 | |
| Total finishing expense | | $0.831 |
| Loading and shipping: | | $0.194 |
| Total | | $1.451 |

### DETAILS OF MILLING COSTS

Cost per ton

| | Labor | Liability insurance | Coke | Oil | General supplies | Power | Repairs | General | Total |
|---|---|---|---|---|---|---|---|---|---|
| Preliminary milling: | | | | | | | | | |
| Crude-bin expense | $0.0168 | $0.0004 | - | - | - | - | $0.0017 | - | $0.0189 |
| Tramming to Reliance crusher | .1982 | .0047 | - | - | $0.0029 | - | .0020 | - | .2078 |
| Fine crushing and conveying | .0099 | .0002 | - | $0.0043 | .0003 | $0.0185 | .0104 | - | .0436 |
| Drying | .0545 | .0013 | $0.0440 | .0031 | .0029 | .0114 | .0057 | - | .1229 |
| Sampling and conveying | .0071 | .0002 | - | - | .0013 | .0108 | .0135 | - | .0329 |
| Total milling cost to mixing bins | .2865 | .0068 | .0440 | .0074 | .0074 | .0407 | .0333 | - | .4261 |
| Finishing: | | | | | | | | | |
| Mixing-bin expense | .0735 | .0017 | - | - | .0001 | .0070 | .0049 | - | .0872 |
| Fine grinding | .2020 | .0048 | - | .0153 | .0409 | .4075 | .0731 | - | .7436 |
| Total finishing expense | .2755 | .0065 | - | .0153 | .0410 | .4145 | .0780 | - | .8308 |
| Loading and shipping | .1224 | .0029 | - | - | .0634 | - | .0032 | $0.0018 | .1937 |
| Total | .6844 | .0162 | .0440 | .0227 | .1118 | .4552 | .1145 | .0018 | 1.4506 |

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## MILLING COSTS PER TON IN UNITS OF POWER AND LABOR

Period covered - 1929. Tons produced - 34,108.

| | Man-hours per ton | Kw.h. per ton |
|---|---|---|
| **Preliminary milling:** | | |
| Crude bins | 0.056 | |
| Tramming to Reliance crusher | .660 | |
| Fine crushing and conveying | .033 | 1.4 |
| Drying | .182 | .9 |
| Sampling and conveying | .024 | .9 |
| Total milling cost to mixing bins | .955 | 3.2 |
| **Finishing:** | | |
| Mixing bins | .141 | .5 |
| Fine grinding | .386 | 32.5 |
| Total finishing expense | .527 | 33.0 |
| Loading and shipping | .414 | |
| Total | 1.896 | 36.2 |

## COST IN DOLLARS AND IN UNITS OF POWER AND LABOR OF GRINDING FELDSPAR TO VARIOUS SIZES

Period covered - 1929. Tons produced - 34,108.

| Mesh | Total tons ground | Total grinding time, hours | Grinding rate, tons per hour | Grinding cost, dollars | | | | Kw.h. per ton | Man-hours per ton |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Labor[1] | Power | Supplies | Total | | |
| 230 | 478 | 328 | 1.52 | $0.465 | $0.684 | $0.221 | $1.370 | 51 | 0.817 |
| 200 | 9150 | 4841 | 1.89 | .373 | .550 | .178 | 1.101 | 41 | .657 |
| 170 | 2786 | 1266 | 2.20 | .321 | .472 | .153 | .946 | 36 | .565 |
| 140 | 4409 | 1868 | 2.36 | .300 | .440 | .142 | .882 | 33 | .526 |
| 120 | 82 | 33 | 2.44 | .290 | .426 | .137 | .853 | 32 | .509 |
| 100 | 57 | 23 | 2.51 | .282 | .413 | .134 | .829 | 31 | .495 |
| 80 | 25 | 10 | 2.56 | .276 | .406 | .131 | .813 | 30 | .485 |
| 60 | 42 | 16 | 2.66 | .266 | .390 | .126 | .782 | 29 | .467 |
| 40 | 462 | 163 | 2.84 | .249 | .366 | .118 | .733 | 27 | .437 |
| 20 | 16597 | 5045 | 3.29 | .215 | .316 | .102 | .633 | 24 | .377 |
| **Total** | 34108 | 13593 | | | | | | | |
| **Average** | | | 2.51 | $0.282 | $0.414 | $0.134 | $0.831 | 33 | 0.527 |

[1] - Includes workmen's compensation and public-liability insurance.

Figure 13 shows the cost and rate of grinding feldspar to various sizes.

## WAGE SCALE - 1930

| Number of men employed | Rate per hour, cents. |
|---|---|
| 1 watchman | 25 |
| 10 trammers of crude spar | 30 |
| 4 loaders and other labor | 30 |
| 2 mix rollers | 32.5 |
| 2 dryer operators | 32.5 |
| 3 separator operators | 35 |
| 1 tram foreman | 35 |
| 3 grinding-mill operators | 37.5 |
| 3 roll operators | 37.5 |
| 3 carpenters and repair men | 40 |
| 1 roll foreman | 50 |
| 1 mill foreman | 50 |
| 1 repair foremn | 55 |
| 1 teamster and team | 60 |
| 36 | |

In addition to the above there are the mill superintendent, five men in the chemical laboratory, three office workers, and a scale man on a monthly salary basis.

The fine-grinding plant and separator sections of the glasspar unit are run 24 hours per day. The other departments are run one or two 10-hour shifts depending on business.

## SAFETY ORGANIZATION

A safety committee has been holding regular monthly meetings for the past two years. It is composed of the mine and mill superintendents, the scale man, timekeeper, repair foreman, office manager, chief chemist, and general manager.

Members of the committee alternate in making weekly inspections of the plant. Their reports are acted upon at the monthly meeting when each accident is discussed and remedial action taken. General meetings of all employees are held semi-annually and talks are given by committee members on safety and accident prevention.

A safety contest is being held monthly between the four departments. A prize is given at Christmas for the best safety suggestion submitted during the year.

Seventeen lost-time accidents during 1930 resulted in a rate of 2.460 days lost per thousand man-hours worked. The employees are intelligently cooperating to better this record in 1931.

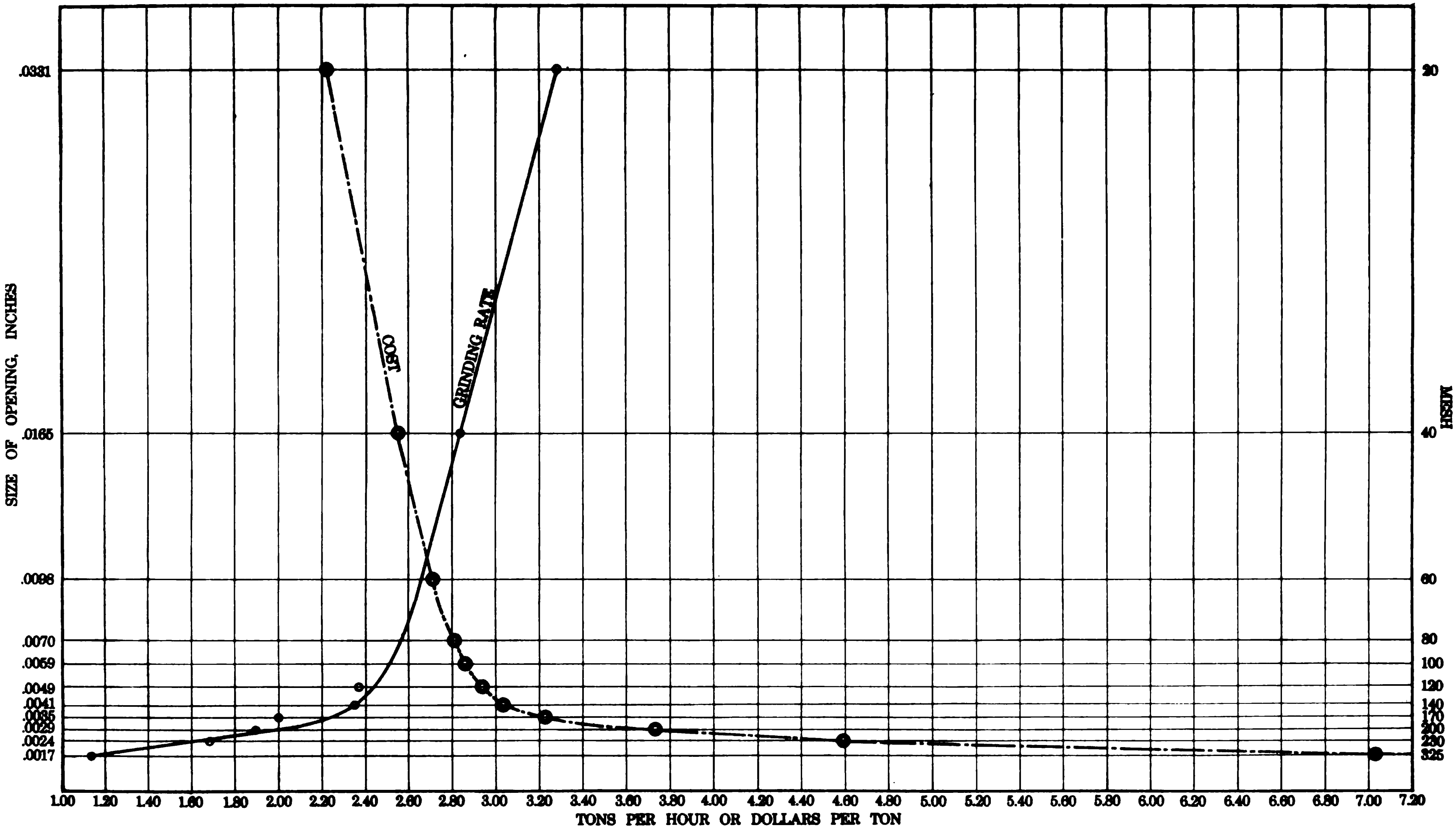

Figure 13.—Cost and rate of grinding feldspar to various sizes